

METHOD OF FORMING POLY-SILICON THIN FILM TRANSISTORS

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Field of the Invention

The present invention relates to a method of forming a poly-silicon thin film transistor, and more particularly, to a method of changing an amorphous silicon thin film transistor directly into a poly-silicon thin film transistor.

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Background of the Invention

Thin film transistors (TFT) have generally been used as devices for active matrix liquid crystal displays (AMLCD). The thin film transistors usually have two types of amorphous silicon (a-Si) and poly-silicon (poly-Si) for different silicon films. The 15 mobility of an a-Si TFT is only about $0.5\text{-}1 \text{ cm}^2/\text{V}\cdot\text{s}$, but a poly-Si TFT has much higher mobility for better crystal character and fewer crystal defects in poly-Si. Therefore, displays fabricated from poly-Si TFT have advantages of high response speed, high resolution, and integrated driver circuits.

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There are some drawbacks such as lower product yield, complex processes, and high process cost existing in the poly-Si TFT fabrication. In contrast, a-Si TFTs are mainly fabricated for displays with a lower process cost and well-developed techniques.

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Owing to the bottleneck of crystallization techniques, the poly-Si TFT is still not

the market mainstream; the conventional methods for fabricating poly-Si films are solid phase crystallization (SPC), excimer laser annealing (ELA), and metal induced lateral crystallization (MILC). SPC is not applicable to flat panel display fabrication because the upper limit temperature of a glass substrate is 650 °C, while ELA has 5 drawbacks of the high cost for laser light, process stability, and poor crystal uniformity. Besides, MILC may have problems in metal diffusion. Therefore, present poly-Si forming methods have technical problems and higher production cost for more complex processes. So the poly-Si TFT is still unable to compete with the a-Si TFT.

10 Further, because the technical problems in poly-Si films fabrication have not been overcome, some manufacturing difficulties exist if the poly-Si TFT fabrication present is utilized to develop large-size displays.

Summary of the Invention

15 An objective of the present invention is to provide a method of forming poly-Si TFT for improving the flat panel display performance. The poly-Si TFT with high mobility can be produced and the superiority in a-Si TFT fabrication also can be kept at the same time. Each film material has different absorption of infrared rays (IR); a metal film with good absorption of IR and thermal stability is used as a hot plate, and 20 the metal film serving as the hot plate absorbs heat energy from the IR by IR heating after producing an a-Si TFT. Then, the metal film transfers the heat energy to the a-Si layer, and the a-Si layer crystallizes to become a poly-Si layer, thus forming a poly-Si TFT.

25 According to one preferred embodiment of this invention, a bottom-gate a-Si

TFT with back channel etch (BCE) structural type is produced on a substrate, and then IR heating is performed. A gate metal and a source/drain (S/D) metal in the a-Si TFT absorb heat energy from the IR rapidly and transfer the heat energy to the a-Si layer; the a-Si layer is therefore induced to crystallize and become a poly-Si layer. Thus, a
5 BCE-type a-Si TFT is transformed into a BCE-type poly-Si TFT.

According to another preferred embodiment of this invention, a bottom-gate a-Si TFT with channel protect (CHP) structural type is produced on a substrate, and then IR heating is performed. A gate metal and a S/D metal in the a-Si TFT absorb heat
10 energy from the IR rapidly and transfer the heat energy to the a-Si layer; the a-Si layer is therefore induced to crystallize and become a poly-Si layer. Thus, a CHP-type a-Si TFT is transformed into a CHP-type poly-Si TFT.

According to still another preferred embodiment of this invention, a top-gate
15 a-Si TFT is produced on a substrate, and then IR heating is performed. In the same way, a gate metal and a S/D metal in the a-Si TFT absorb heat energy from the IR rapidly and transfer the heat energy to the a-Si layer; the a-Si layer is therefore induced to crystallize and become a poly-Si layer. Thus, a top-gate a-Si TFT is transformed into a top-gate poly-Si TFT.

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With the application of the present invention, in addition to preserving the superiority of a-Si TFT fabrication, the poly-Si TFT with good electrical performance is also formed. Thus, the driver circuits can be integrated on a panel to reduce the cost of adding driver circuits to the a-Si TFT.

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Further, the poly-Si TFT devices formed by the present invention are useful for improving the liquid crystal display (LCD) performance and even employed to drive the organic light-emitting display (OLED).

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Brief Description of the Drawings

The foregoing aspects and many of the attendant advantages of this invention will become more readily appreciated as the same becomes better understood by reference to the following detailed description, when taken in conjunction with the accompanying drawings, wherein:

10 FIGS. 1A-1C are cross-sectional schematic diagrams showing the process for forming a poly-Si TFT in accordance with the first preferred embodiment of the present invention;

15 FIGS. 2A-2D are cross-sectional schematic diagrams showing the process for forming a poly-Si TFT in accordance with the second preferred embodiment of the present invention; and

FIGS. 3A-3C are cross-sectional schematic diagrams showing the process for forming a poly-Si TFT in accordance with the third preferred embodiment of the present invention.

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Detailed Description of the Preferred Embodiments

The present invention utilizes the different IR absorption of various film materials; the IR heating process is performed on an a-Si TFT product, and the film material with higher IR absorption and good thermal stability absorbs heat energy from the IR and transfers the heat energy to the a-Si layer. The a-Si layer consequently 25 crystallizes to become a poly-Si layer. Hot plate crystallization (HPC) technique is

utilized, the film material with higher IR absorption and good thermal stability in the TFT is used as a hot plate, and then the hot plate transfers heat to the a-Si layer to induce crystallization in the a-Si layer. The a-Si layer is thus changed into the poly-Si layer. Therefore, the IR heating process is merely added after the a-Si TFT fabrication processes without changing the general processes and process conditions in the a-Si TFT fabrication, and then the poly-Si TFT is directly obtained from the a-Si TFT.

The metal film is the film material with higher IR absorption and good thermal stability apparently in the TFT devices, and therefore a gate metal and a source/drain (S/D) metal all can be used as the hot plates for absorbing heat energy from the IR. Then, the a-Si layer is crystallized by obtaining the heat energy transferred from the metal films; the a-Si layer is thus effectively changed into the poly-Si layer, and the poly-Si TFT is formed.

The poly-Si TFT is formed by combining the present a-Si TFT fabrication processes with the present invention. According to differences in the TFT structure, there are two kinds of bottom-gate and top-gate structures. The bottom-gate structure further comprises two types of BCE and CHP structure generally used in the a-Si TFT fabrication. The method of forming the poly-Si TFT in accordance with the present invention is combined with the foregoing TFT structures respectively to produce the poly-Si TFT.

Embodiment 1

The present invention discloses a method of forming the poly-Si TFT combined

with the bottom-gate BCE structural type. Referring to FIG. 1A, a gate metal 102 is first formed on a substrate 100 by, for example, physical vapor deposition (PVD), and is then patterned by, for example, photolithography and etching. The substrate 100 may be a glass substrate, and the gate metal 102 is a material with good electric 5 conductivity such as chromium (Cr), molybdenum (Mo) or moly-tungsten (MoW), and the gate metal 102 is also a material with good IR absorption and thermal stability.

A gate insulator 104, an amorphous silicon (a-Si) layer 106, and a doped a-Si 10 layer 108 are formed in turn on the gate metal 102 and the substrate 100 simultaneously by, for example, plasma enhanced chemical vapor deposition (PECVD), and the preferred material of the gate insulator 104 is silicon nitride (SiN_x) or silicon oxide (SiO_x). Then, the a-Si layer 106 and the doped a-Si layer 108 are patterned partially by, for example, photolithography and etching to form an active layer region (not shown).

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Next, referring to FIG. 1B, a S/D metal 110 is formed by, for example, PVD, and is patterned by, for example, photolithography and etching to form a data-line. The S/D metal 110 is a material with good electric conductivity such as Cr, Mo or MoW, and the S/D metal 110 is also a material with good IR absorption and thermal 20 stability. Then, with the S/D metal 110 serving as a hard mask, the doped a-Si layer 108 between the S/D metal 110 is etched to form an opening 112 exposing a portion of the a-Si layer 106; the a-Si layer 106 in the opening 112 represents a channel region.

The a-Si TFT is finished through the aforementioned processes; then, referring 25 to FIG. 1C, the heating process with an IR 114 is utilized, and the a-Si TFT is directly

changed into the poly-Si TFT.

The heating process with the IR 114 can utilize any IR supply method; the preferable method in the present invention is a pulsed rapid thermal processing (PRTP) technology. Because of the film materials with different IR absorption, the TFT is heated selectively by the IR 114. The gate metal 102 and the S/D metal 110 have higher IR absorption and so absorb heat energy from the IR 114 rapidly. Therefore, the gate metal 102 and the S/D metal 110 are heated selectively to serve as the hot plates for transferring the heat energy to the doped a-Si layer 108 and the a-Si layer 106, and then the doped a-Si layer 108 and the a-Si layer 106 are induced to crystallize to become a doped poly-Si layer 109 and a poly-Si layer 107. The poly-Si TFT is thus formed.

The highest corresponding output temperature of the heating process is preferably about 900 °C. The proportion occupied by metal films in the TFT is sufficient to transfer the heat energy absorbed by the doped a-Si layer 108 and the a-Si layer 106 for forming a poly-Si. The heating process employed is a pulsed heating process, not a continuous heating, and heats the film materials in the TFT selectively. Further, a glass substrate is unable to absorb the IR 114 effectively, so the device property is not affected and there are no glass substrate deformation problems associated with the process temperature.

Embodiment 2

The present invention discloses another method of forming the poly-Si TFT combined with the bottom-gate CHP structural type. Referring to FIG. 2A, a gate

metal 202 is first formed on a substrate 200 by, for example, PVD, and is then patterned by, for example, photolithography and etching. The substrate 200 may be a glass substrate, and the gate metal 202 is a material with good electric conductivity such as Cr, Mo or MoW; the gate metal 202 is also a material with good IR absorption
5 and thermal stability.

A gate insulator 204, an a-Si layer 206, and a protective layer 208 are formed in turn on the gate metal 202 and the substrate 200 simultaneously by, for example, PECVD, and the preferred material of the gate insulator 204 and the protective layer
10 208 is SiN_x or SiO_x.

Referring to FIG. 2B, the protective layer 208 is patterned by, for example, photolithography and etching to form an etching stop layer 209 for protecting the channel region. Then, a doped a-Si layer 210 is formed on the a-Si layer 206 by, for
15 example, PECVD. The a-Si layer 206 and the doped a-Si layer 210 are patterned partially by, for example, photolithography and etching to form an active layer region (not shown).

Next, referring to FIG. 2C, a S/D metal 212 is formed by, for example, PVD,
20 and is patterned by, for example, photolithography and etching to form a data-line. The S/D metal 212 is a material with good electric conductivity such as Cr, Mo or MoW, and the S/D metal 110 is also a material with good IR absorption and thermal stability. Then, with the S/D metal 212 serving as a hard mask, the doped a-Si layer 210 between the S/D metal 212 is etched to form an opening 214 exposing the etching
25 stop layer 209. The a-Si layer 206 under the etching stop layer 209 represents the

channel region. Because the etching stop layer 209 protects the a-Si layer 206, the etching for the doped a-Si layer 210 stops at the etching stop layer 209 and avoids damaging the a-Si layer 206 under the etching stop layer 209.

5 The a-Si TFT is finished through the aforementioned processes. With reference to FIG. 2D, the heating process with an IR 216 is utilized, and the a-Si TFT is directly changed into a poly-Si TFT.

The heating process with the IR 216 in the present invention is also preferably
10 PRTP technology, and the TFT is heated selectively by the rapid heating process. The highest corresponding output temperature of the heating process is preferably about 900 °C. With the gate metal 202 and the S/D metal 212 serving as hot plates to absorb heat energy from the IR 216 rapidly and then transfer the heat energy to the doped a-Si layer 210 and the a-Si layer 206, and the doped a-Si layer 210 and the a-Si
15 layer 206 are induced to crystallize and become a doped poly-Si layer 211 and a poly-Si layer 207. The poly-Si TFT is thus formed.

Embodiment 3

The present invention discloses further another method of forming the poly-Si
20 TFT combined with the top-gate structural type. Referring to FIG. 3A, a buffer layer 302 is first formed on a substrate 300 by, for example, PECVD. The substrate 300 may be a glass substrate, and the buffer layer 302 may be a SiO_x layer. Then, an a-Si layer 304 is formed on the buffer layer 302 by, for example, PECVD.

25 Next, a gate insulator 306 is formed on the a-Si layer 304 by, for example,

PECVD; the preferred material of the gate insulator 306 is SiO_x . A gate metal 308 is formed by, for example, PVD, and is then patterned by, for example, photolithography and etching. The gate metal 308 is a material with good electric conductivity such as Cr, Mo or MoW, and the gate metal 308 is also a material with good IR absorption and
5 thermal stability.

Then, referring to FIG. 3B, an ion-implantation is performed, with the gate metal 308 serving as a mask, and the a-Si layer 304 on two sides of the gate-metal 308 is implanted with ions to define a S/D region. A dielectric interlayer 310 is deposited by,
10 for example, PECVD, and is then patterned by, for example, photolithography and etching to form contact holes 311 which exposes the S/D region. The preferred material of the dielectric interlayer 310 is SiN_x or SiO_x .

Finally, a S/D metal 312 is formed by, for example, PVD, and is then patterned
15 by, for example, photolithography and etching to form a data line. The S/D metal 312 is on the dielectric interlayer 310 and in the contact holes 311 to contact the a-Si layer 304 in the S/D region. The S/D metal 312 is a material with good electric conductivity such as Cr, Mo or MoW, and the S/D metal 312 is also a material with good IR absorption and thermal stability.

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The a-Si TFT is finished through the aforementioned processes. With reference to FIG. 3C, the heating process with an IR 314 is utilized, and the a-Si TFT is directly changed into the poly-Si TFT.

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The heating process with the IR 314 in the present invention is also preferably a

P RTP technology, and the TFT is heated selectively by the rapid heating process. The highest corresponding output temperature of the heating proves is preferably about 900 °C. With the gate metal 308 and the S/D metal 312 serving as hot plates to absorb heat energy from the IR 314 rapidly and then transfer the heat energy to the a-Si layer 5 304, and the a-Si layer 304 is induced to crystallize and become a poly-Si layer 205. The poly-Si TFT is thus formed.

With the foregoing embodiments, the only addition to the general a-Si TFT fabrication processes is the IR heating. The metal film materials in the TFT then 10 absorb heat energy from the IR and transfer the heat energy to the a-Si layer, and the a-Si layer is induced to crystallize and become a poly-Si layer. Therefore, the a-Si TFT can be changed directly into a poly-Si TFT by employing the IR heating. The poly-Si TFT formed by the present invention can keep the advantages of the a-Si TFT fabrication and have a better electrical performance at the same time.

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In addition to the LCD, the present invention also can be employed to fabricate a poly-Si TFT for driving the OLED, and then the product performance is improved greatly.

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The present invention is not limited employed in TFT fabrication for flat panel display; other poly-Si TFT devices also can be fabricated by using the present invention to improve product efficiency. While the present invention has been disclosed with reference to the preferred embodiments of the present invention, it should not be considered as limited thereby. Various possible modifications and 25 alterations by one skilled in the art can be included within the spirit and scope of the

present invention, the scope of the invention is determined by the claims that follow.